ECN

Energy research Centre of the Netherlands

The sustainability of PV: is it quantifiable in external costs?

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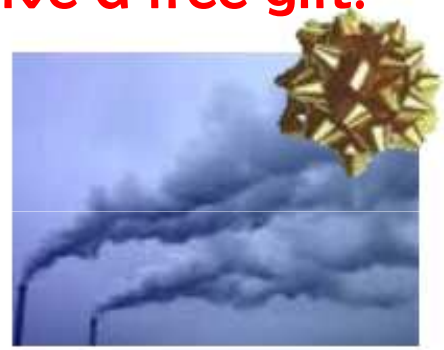
What is an external cost?

Def'n: A cost that's not included in the market price of a good because it's not included in the supply price;

With Every Purchase of  or  , You receive a free gift!



The risk of external costs is transferred to the public. The price of the consequences is paid with your tax money !




Outline: putting the spotlight on external costs

1) **External costs of nuclear:**
   - Focus on subsidies
2) **External costs of coal:**
   - Focus on monetarizing effects of emissions
3) **External costs of PV:**
   - subsidies and emissions & land use
4) **Comparison and discussion of sustainability**

The cost of electricity from different technologies is compared using the levelized cost of electricity (LCOE)

What is the Levelized Cost of Electricity?

Levelized cost (often expressed in $/MWh or ¢/kWh) represents the present value of the **total cost of building and operating a generating plant** per unit electricity produced, over an assumed **financial life and duty cycle.**

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Levelized Cost of Electricity for PV, Coal and Nuclear

Estimated Levelized Cost of New Generation Resources, 2016

Plant Type	Capacity Factor (%)	U.S. Average Levelized Costs(2009 $/megawatthour) for Plants Entering Service in 2016				
		Levelized Capital Cost	Fixed O&M	Variable O&M (including fuel)	Transmission Investment	Total System Levelized Cost
Coal	85	65.3	3.9	24.3	1.2	94.8
Advanced Nuclear	90	90.1	11.1	11.7	1	113.9
Solar PV	25	194.6	12.1	0	4	210.7

Source: Energy Information Administration, Annual Energy Outlook 2011, December 2010, DOE/EIA-0383(2010)

LCOE Breakdown

	Plant Characteristics		Plant Costs		
	Nominal Capacity (kilowatts)	Heat Rate (Btu/kWh)	Overnight Capital Cost (2010 $/kW)	Fixed O&M Cost (2010$/kW)	Variable O&M Cost (2010 $/MWh)
Single Unit **Adv. Pulv. Coal**	650,000	8,800	$3,167	$35.97	$4.25
Dual Unit Adv. Pulv. Coal	1,300,000	8,800	$2,844	$29.67	$4.25
Dual Unit Nuclear	2,236,000	N/A	$5,335	$88.75	$2.04
Small Photovoltaic	7,000	N/A	$6,050	$26.04	$0.00
Large Photovoltaic	150,000	N/A	$4,755	$16.70	$0.00

Comparison of Updated Plant Costs to *AEO2010* Plant Costs

	Overnight Capital Cost ($/kW)			Nominal Capacity kW's[1]	
	AEO 2011	AEO 2010	% Change	AEO 2011	AEO 2010
Adv.Pulv. Coal	$2,844	$2,271	**25%**	1,300,000	600,000
Nuclear	$5,339	$3,902	**37%**	2,236,000	1,350,000
Photovoltaic	$4,755	$6,303	**-25%**	150,000	5,000

1 Higher plant capacity reflects the assumption that plants would install multiple units per site and that savings could be gained by eliminating redundancies and combining services.

Energy Information Administration, Annual Energy Outlook 2011, December 2010, DOE/EIA-0383(2010)

LCOE for nuclear

Overnight costs:

No construction time period

& no interest rates on the construction

Significant cost cut for nuclear:

large capital outlays and high financing costs (15%)

Construction times average 11 -12 years.

Each 10 year construction period increases capital costs 200%!

Capacity factor:

Assumed in EIAs calculations: 90 %

Actual data average: 71-79%.

1-1.5% cost cuts per 1% capacity factor improvement

→10%-28% improvement in costs!

Schrader-Frechette, Sci Eng Ethics (2011) 17:75-107 and refs therein

Nuclear LCOE vs. Subsidies

In addition to paying at least half of the capital costs, the public also pays for part or all of the costs for*:

- Operating the plant
- Uranium fuel
- Insurance & liability
- Plant security, proliferation
- Cooling water
- Waste disposal & plant decommissioning

EIA's LCOE does not include the public costs of nuclear power‡.

"National Energy Modeling System generally reflects all current legislation and regulation…"

*Koplow, D., Union of Concerned Scientists report, http://www.ucsusa.org/nuclear_power/nuclear_power_and_global_warming/nuclear-power-subsidies-report.html

‡ http://www.eia.gov/forecasts/aeo/assumptions/index.cfm

Fukushima nuclear disaster: Utility insurance can't cover the cost.

External costs:
Public aid to pay massive costs of TEPCO accident

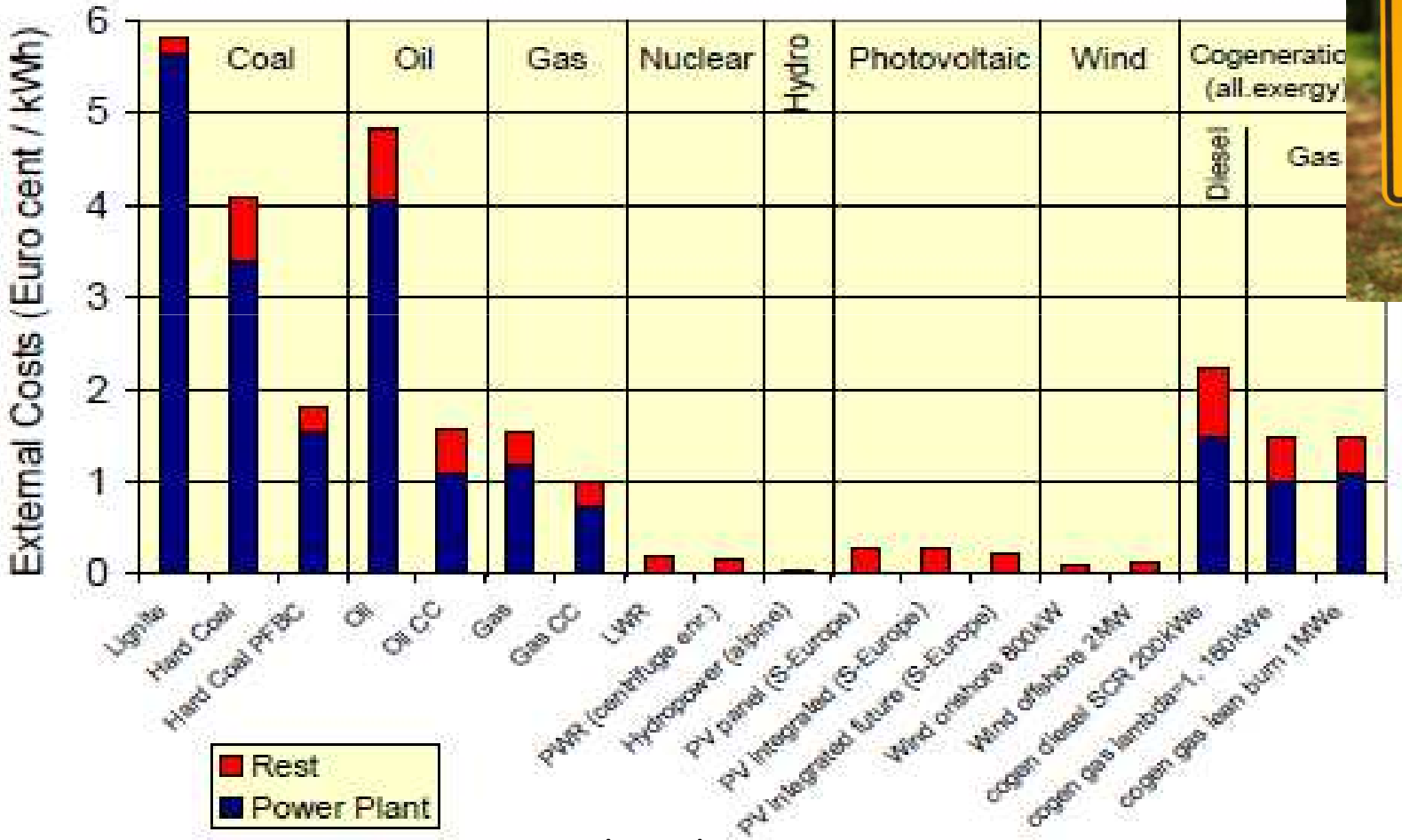
Damage on-going:
Cold shut-down in 2012

Current estimates:
¥ 1-2 trillion = $ 13 billion

calculations of external costs

Fig.9. External costs of current and advanced electricity systems, associated with emissions from the operation of power plant and with the rest of energy chain.

a) the costs in €cent/kWh



ExternE-Pol Final Report, 2005, Contract No ENG1-CT-2002-00609

Coal: Focus on effects of emissions

Mining


Refining


Shipping


Power Plant

Coal, like other fossil fuels, receives many subsidies:

Environmental and Energy Study Institute, “Fossil Fuel Subsidies: A Closer Look at Tax Breaks, Special Accounting, and Societal Costs”, www.eesi.org

external costs of coal

	estimates in ¢/kWh			
	Low	Best	High	
LAND	0,47	0,53	0,95	3%
HEALTH	7,7	14,09	15,48	79%
CLIMATE	1,02	3,06	10,21	17%
SUBSIDIES	0,16	0,16	0,27	1%
Total	**9,35**	**17,84**	**26,91**	100%

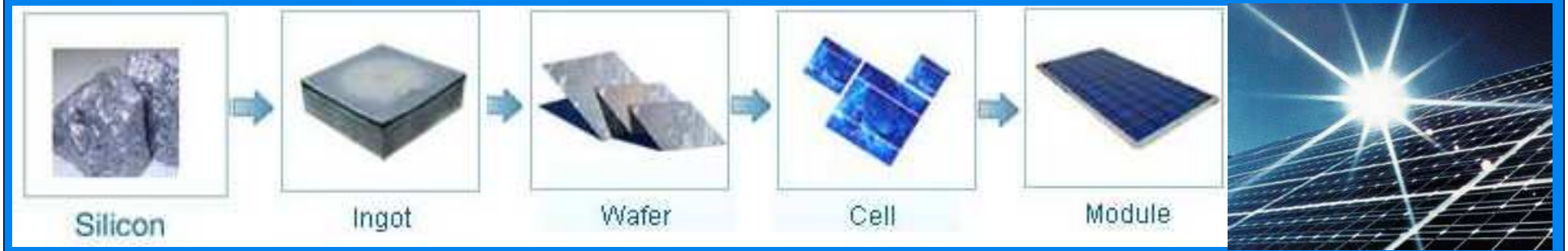
Cost of coal: 9 – 27 ¢/kWh in addition to price of generation

Omitting:

"impacts of toxic chemicals & heavy metals on ecological systems; risks & hazards of sludge, slurry and fly ash impoundments; effects of nitrogen deposition in water; impacts of acid rain and acid mine drainage; full assessment of impacts due to increasingly unstable climate"

Epstein, P. et al, Ann. N.Y. Acad. Sci. 1219 (2011) 73-98

external costs of PV: subsidies



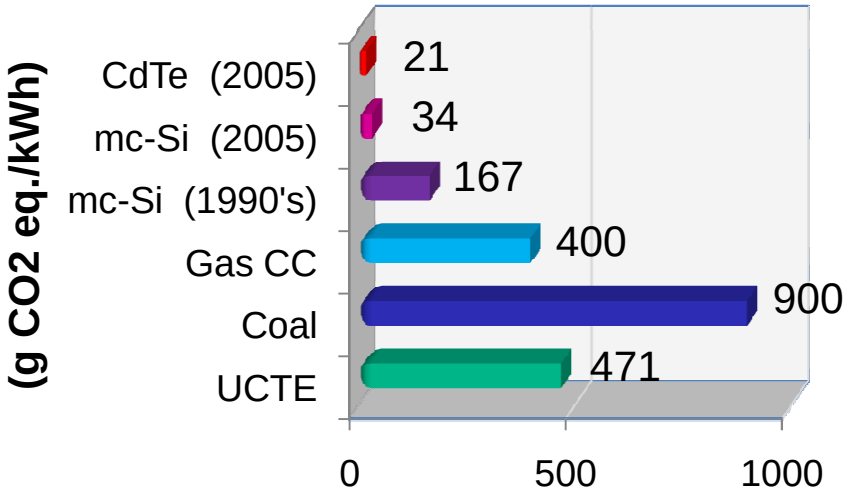
External costs from:

- Greenhouse Gas Emissions
- Subsidies
- Land Use
- Other possible externalities

PV: greenhouse gas emissions

Emissions:

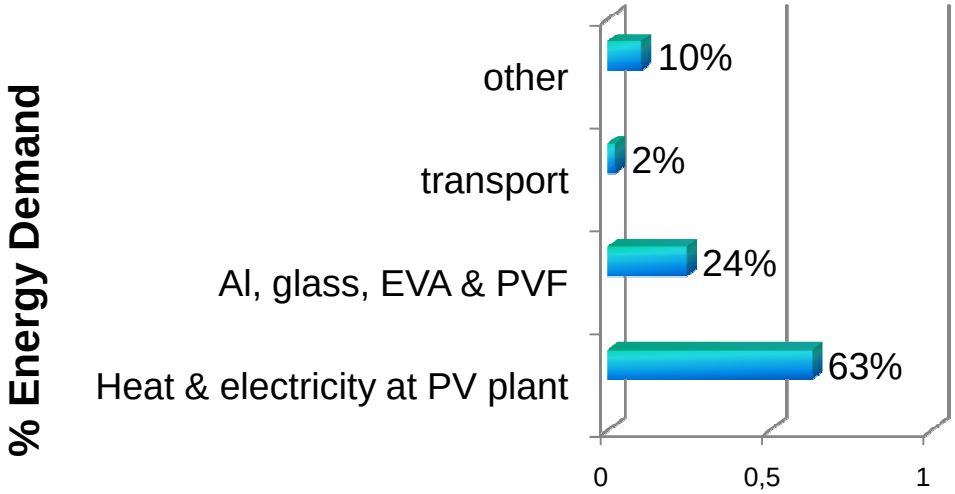
Typical greenhouse gas emissions for rooftop PV systems, using UCTE electricity mix while manufacturing‡



Split up emissions:*

Direct: Kerf loss, F-gas PECVD cleaning, incineration of encapsulants

Indirect: Heat & electricity



xSi module (omitting BOS): 24 g CO_2 eq/kWh (2010)

‡Raugei, Energy 34 (2009) 392-399; Reich et al., Prog. Photovolt: Res. Appl. 19:603-613 (2011)*

PV: land use

Land use:

Example: US, high electricity bill

"Contrary to popular opinion, *a world relying on PV would offer a landscape almost indistinguishable from the landscape we know today.*"

Area to provide all US electricity from PV

- 7% of area of cities and residences (no new land)
- < 2% of the US crop and grazing land (reallocation)
- less than is currently used to produce corn for ethanol
- less land than is used for coal (including mining operations)

http://www.nrel.gov/docs/fy04osti/35097.pdf; Paul Denholm, Robert M. Margolis, Land-use requirements and the per-capita solar footprint for photovoltaic generation in the United States, Energy Policy, Volume 36, Issue 9, September 2008, Pages 3531-3543, ISSN 0301-4215, DOI: 10.1016/j.enpol.2008.05.035.

PV: other possible externalities

2 possible ways for PV external costs to accrue

Unsustainable manufacturing practices:

e.g. Washington Post reported $SiCl_4$ dumping in China by the Luoyang Zhonggui High-Technology Co. (2008)

End-of-life disposal/recycling of solar modules:

e.g. Currently electronic waste is a problem.

PV CYCLE

PV: subsidies

Feed-in-tariff subsidies give a preference to renewable generated electricity in order to grow the renewable energy sector

Environmental effects:

Climate and health benefits from lower emissions

No new land needed

Economic effects:

Job creation: 164% more jobs from solar than oil*

Economic stability - Less volatile prices

Assuming sustainable manufacturing and end-of-life solutions for PV modules, there is **no risk** transferred to the public.

*Pollin, R. , Political Economy Research Institute, June 2009

Yes. The sustainability of PV is evident from quantified external costs.

Low-end estimates of external costs would put the cost of nuclear and coal at least 2-3 times those stated, which are admittedly rapidly increasing for both. This shows that:

- PV is indeed more sustainable and more truly economical than the coal and nuclear options.
- No free market for electricity pricing.

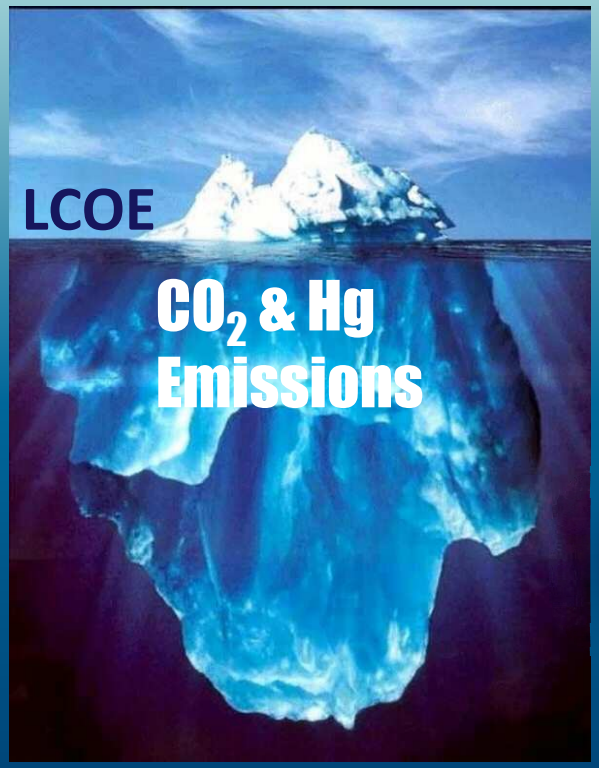
However, 'It's not over 'til it's over.'

- PV industry/community must keep an eye on sustainable processing and end-of-life solutions.

Thank you for your attention.

Nuclear Costs

Coal Costs



PV Costs

This work was undertaken as part of The PV Parity project, which started in June 2011 and will end in May 2014. The PV Parity project is co-financed by the European Commission in the framework of the Intelligent Energy Europe (IEE) Program.